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Forsyth, Raymond A.; and Harold A. Munday

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Introduction

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One of the most common methods for preventing or retarding reflection cracking has been the use of a flexible bases cushion course, (untreated aggregate base) and the California Division of Highways has had rather extensive experience with this form of construction. Since many of these jobs are over ten years old, it was decide to check on the field performance of these projects, and on certain selected jobs to perform a rather extensive field and laboratory survey.

The purpose of this report is to provide information on the findings from this study. The methods employed in the evaluation included:

1. A review of the literature on resurfacing of old pavements throughout the United States.
2. A review of past reports of failures involving flexible cushion courses in California.
3. A visual inspection of cushion course projects in California Highway Districts 05, 06, and 10.
4. Field investigation of five cushion course projects in California.

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STATE OF CALIFORNIA
HIGHWAY TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

THE EFFECTIVENESS OF FLEXIBLE BASE CUSHION COURSES OVER OLD PAVEMENTS

January 1966

66-29

State of California
Department of Public Works
Division of Highways
Materials and Research Department

January 14, 1966

Lab. Auth. 430738

Mr. J. C. Womack
State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

REPORT

on

THE EFFECTIVENESS OF

FLEXIBLE BASE CUSHION

COURSES OVER OLD PAVEMENTS

Study made by . . . . Pavement Section
Under Direction of . . . . Ernest Zube
Project Supervisor . . . . Raymond A. Forsyth
Report Prepared by . . . . Raymond A. Forsyth
Harold A. Munday

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

Attachment
cc: LRGillis
ACEstep
CGBeer (9)
JFJorgensen

INTRODUCTION

Reflection cracking is of primary importance with respect to A.C. overlays of existing concrete pavements and in some instances also of A.C. surfacings. A number of methods have been tried for retarding or preventing reflection cracking, and some of these have been used by the California Division of Highways either in normal construction practice or in experimental test projects.

One of the most common methods for preventing or retarding reflection cracking has been the use of a flexible base cushion course, (untreated aggregate base) and the California Division of Highways has had rather extensive experience with this form of construction. Since many of these jobs are over ten years old, it was decided to check on the field performance of these projects, and on certain selected jobs to perform a rather extensive field and laboratory survey.

The purpose of this report is to provide information on the findings from this study. The methods employed in the evaluation included:

1. A review of the literature on resurfacing of old pavements throughout the United States.
2. A review of past reports of failures involving flexible cushion courses in California.
3. A visual inspection of cushion course projects in California Highway Districts 05, 06 and 10.
4. Field investigation of five cushion course projects in California.

CONCLUSIONS

The primary objective of this report has been an evaluation of the effectiveness of flexible cushion courses in California.

From a review of the literature on the subject of overlays of existing roadways, it is apparent that the problem of reflection cracking has been approached in many ways with varying degrees of success. These methods have included:

1. Additives in the A.C. binder to increase ductility.
2. Breaking the bond between resurfacing and old pavement for greater stretch distribution.
3. The use of special joint fillers.
4. Wire mesh reinforcement of A.C. surfacing overlays.
5. The use of thick (4" to 6") contact blankets.

6. Pavement breaker rolling.

7. Flexible cushion course construction.

Although all of these methods have been successful to a certain extent, it would seem that numbers 4, 5, 6 and 7 have been most consistently effective in the reduction of reflection cracking.

The use of wire mesh reinforcement is, however, in too early a stage of development for an absolute determination of its worth. There appears to be a definite possibility that average quality wire mesh cannot be used for extended periods of time without rusting or corroding through however.

The use of thick contact blankets has proven generally effective, particularly when the old slabs have been subsealed. This method of reconstruction is, however, expensive and presents difficulties if the existing super elevation or crown is to be altered by the reconstruction.

It appears that the States of Minnesota and Washington, in independent investigations, have had excellent results by breaking concrete pavement slabs with heavy rollers (59 tons). The State of Minnesota subsequently resurfaced the broken slabs with an A.C. blanket, while the State of Washington chose to place an aggregate base cushion course prior to the placement of an A.C. surfacing.

In reviewing available reports of investigations of failed cushion course sections in California, one project stands out as probably the primary reason for the curtailment of this construction technique in California. This roadway, X-Sol-7,8-H,B,A, contract 1-10TC62-F, near Cordelia was completed in 1953 and failed immediately after its opening to traffic and the distress necessitated a blanketing operation before the contract was actually accepted.

A review of the circumstances pertinent to the distress on this roadway, however, leads the writers to believe that under similar circumstances, it is doubtful that any new construction would have remained undistressed. In this case 14" of rainfall through a new A.C. pavement unsealed by traffic and in a relatively permeable state resulted in a complete and early disintegration of the surfacing. The fact that this roadway was a cushion course, is, in the writer's opinion, of academic interest only since any system would have been saturated for an extended period of time under similar conditions.

It is a well known fact that an average quality subbase material is not what could be considered free draining. Indeed, aggregate bases of average quality have been shown to have amazingly low permeability rates. Thus the presence of an old concrete pavement or a relatively impermeable aggregate subbase will result in the same condition with respect to the drainage potential of the structural section. This was illustrated by a later investigation of road X-Sol-7-B, (Detour) in which a new surfacing exposed to heavy rainfall before it could be sealed by traffic, failed within two weeks of its opening to the heavy truck traffic of U.S. Highway 40. Here again, the structural section was adequate, however, the surfacing was shown to be permeable. Large amounts of surface runoff entered the structural section and was trapped for an extended period of time in the base layer by a sandy, slow draining subbase.

It seems reasonable to conclude therefore, that the failure attributed to cushion course construction on project X-Sol-7,8-H,B,A, would have occurred under similar circumstances with any type of flexible pavement construction.

Conversations with District Materials personnel confirm our visual observations that cushion course construction in Districts 05, 06 and 10 has been generally successful. In District 10 in particular, this technique has been used successfully on over 30 projects since 1948.

The results of field investigations of five cushion course projects in which other types of construction were employed indicate that:

1. There was less visual evidence of cracking and rutting on cushion course sections as compared to those consisting of all new construction. This was also generally the case with respect to blanketed sections.

2. The level of transient deflection was lower, in all cases, on cushion course construction than that found on new construction and was generally comparable to that found on the blanketed sections.

3. Although four of the five projects were investigated in the spring, the moisture content of the cushioning base material was, in all cases, well below design moisture criteria (300 psi exudation pressure).

4. The properties of asphalt recovered from cores taken in cushion course sections indicated a lesser degree of aging and hardening than those taken from the new construction. This is possibly due to the generally lower deflection levels on the cushion sections and hence fewer surfacing cracks which made the intimate part of A.C. mix less accessible to air and water.

A review of the literature indicates that cushion course construction has been uniformly successful in other states for the prevention of reflection cracking. In California the incidence of premature failure has not been greater than that for other types of construction and, indeed, generally appears to be less. For the most effective utilization of this technique, however, every effort should be made to complete the paving operation well before the rainy season in order that traffic compaction will have sealed the surfacing prior to the onset of winter rains. It would also appear desirable that the cushion material be as permeable as practically possible and that the cushion layer be "daylighted". Under these circumstances, the chance of entrapment of water will be minimized.

REVIEW OF THE LITERATURE

Reflection cracking is of primary importance with respect to A.C. overlays of existing concrete, and in some instances, A.C. surfacings.

The maintenance problems resulting from the spalling of unhealed reflection cracks may be intensified by deterioration or rapid hardening of the surfacing resulting from the admission of surface runoff. In addition, the riding quality of the resurfaced roadway may be adversely affected.

The mechanics of reflection cracking were examined in detail by Alexander Bone, Lewis W. Crump and Vincent J. Roggeveen[1] in 1954. This paper points out the fact that reflection cracking may result from either vertical or horizontal movement of the concrete slabs.

Vertical movement, which is usually induced by severe curling or erosion of the supporting strata, can be largely eliminated by subsealing or breaking the slabs.

Horizontal movement, which results entirely from moisture content and temperature variations, was found to have a seasonal variation of from 0.10" to 0.18" per 57 feet (the distance between expansion joints in Massachusetts). Because of the roughness of the concrete and natural adhesiveness of an A.C. overlay, this movement is not absorbed throughout any appreciable length so the surfacing immediately adjacent and directly over the concrete joint must conform to the entire contraction.

Unfortunately, at the low temperatures at which maximum contraction takes place, A.C. surfacing is almost entirely in the elastic state. The results of the Bone, Crump and Roggeveen investigation indicate that at 30°F, A.C. surfacing specimens of average quality and 13" in length will not tolerate strains in excess of 0.05" without cracking. These results were verified by field measurements in which it was found that in nearly every instance where the surfacing had stretched more than 0.05", a crack had appeared. The preliminary results from the "Revere" Test Road in Massachusetts, devoted entirely to the problem of crack reflection into bituminous resurfacing, were also discussed.

In this project various methods for the prevention or control of reflective cracking were utilized in several experimental test section overlays of an old concrete pavement. These included:

1. Catalytically blown asphalt blend.
2. Emulsified rubber asphalt.
3. Regular Massachusetts Type I-1 asphalt.
4. Joints leveled with bituminous mix.
5. Metal plates placed directly on concrete across transverse joints.
6. Building paper across joints.
7. Control sections 2½ - 3" thick.
8. Wire mesh reinforcing

The early results of these tests indicated that rubberized asphalt was more crack resistant than the catalytically blown or standard asphalts. There was no indication that the wire mesh reinforcement distributed the stretch over the entire width. The data presented, however, was the result of only one winter of testing.

A later paper (1955) by the same authors[2] presented a general evaluation of methods currently employed for control of reflective cracking. The following is a brief summation of the comments on each method.

1. Breaking Pavement into Small Slabs

   This method destroys the structural integrity of the slab in addition to being expensive and time consuming.

2. Increased Thickness of Surfacing

   This method does help although complete prevention of reflective cracking requires thicknesses greater than the 2½ to 4 inches currently being used. In Massachusetts, it has been found that a 3 inch surfacing will crack over 90% of the joints within three years.

3. Increased "Stretchability"

   Tests have indicated that the ductility of mixes would have to be increased 5 times to accommodate the stretch imposed by slabs 57' long (Massachusetts).

   No such additive is known and it is doubtful that it can be developed without substantially lowering stability.

4. Distribution of Stretch by Breaking Bond Between Surfacing and Concrete Pavement

   This method renders pavement more subject to shoving.

5. Use of Flexible Base Cushion Course

   This method does reduce reflection cracking but is unusable in urban areas where grade controls.

6. Welded Wire Fabric

   Too early to be properly evaluated.

In a study of reflective cracking in Iowa reported by Steven E. Roberts[3] particular emphasis was placed upon width of pavement joints, type of joint filler, and thickness of resurfacing.

It was found that, over cracks less than 1 inch in width, the percentage of reflective cracking was only slightly affected by the type of joint filler. Pronounced reductions were noted, however, by using an extra 1½ inches of surfacing (increasing from 3 to 4½ inches) and to a lesser extent, a higher penetration asphalt binder.

The use of wire mesh reinforcement for the prevention of crack reflection on three test projects was reported by the California Materials and Research Department in 1956[4]. At the time of this report the test sections had been down for approximately 9 to 18 months. A definite and sizeable reduction in the amount of reflective longitudinal cracking through the wire mesh sections as opposed to the control sections was noted. It was observed that continuous wire reinforcement was equivalent in cost to approximately 1½" of A.C. surfacing. Later inspections, however, have failed to indicate a clear cut superiority of the mesh sections, partly because of a subsequent district resurfacing in the largest section (Vallejo) with the other projects being too small to draw definite conclusions.

A subsequent report upon the results of a 5 year study of the effectiveness of welded wire fabric reinforcement of 3 inch A.C. surfacing on two test roads in Massachusetts was made by Tons, Bone, and Roggeveen[5] in 1961. In this test, it was found that the best resistance to reflection cracking was provided by continuous welded wire fabric reinforcement (3 x 6, 10/10) which reduced the reflection of transverse cracks to approximately 1/8 of that in the control sections. The use of strip reinforcement resulted in reductions in reflection cracking of up to 2/3 that found in the control sections. In addition, cracks in the mesh sections were found to be consistently smaller in width than those in the control sections.

Although the results of both of these studies indicate a definite favorable trend, insofar as the effectiveness of wire reinforcement in the reduction of crack reflection, it remains to be seen whether the degree of improvement justifies the added expenditure.

Another approach to the problem of reflective cracking of A.C. blankets over old P.C.C. was presented to the Association of Asphalt Paving Technologists in 1963 by Mr. J. L. Vicelja[6], in which the results of a 4 year study of the effectiveness of expanded wire mesh reinforcement and the use of aluminum foil, wax paper, and stone dust for breaking the bond over existing P.C.C. shrinkage cracks was discussed. Of particular interest was the effectiveness of an 18" swath of stone dust in eliminating bond and thus precluding reflective cracking. On one particular roadway (Washington Avenue, Los Angeles County) after several years of observation this treatment had been completely successful as compared to a total lack of success with expanded wire mesh and partial successes with wax paper and aluminum foil.

This department is presently testing the effectiveness of bond breaking agents on projects 03-Col-7-B,Wlms and 05-SB-148-Gdlp,A (Guadalupe). Preliminary results from these investigations, however, do not indicate any significant reduction in reflection cracking where bond breaking agents are used as compared to the control sections.

In 1950[7] the Minnesota Highway Department reported that the use of flexible base cushion courses appeared to be more effective in the prevention of reflection cracks than 3 inch A.C. concrete overlays. It was stated, however, that "amounts of plastic fines in excess of 10% may cause destructive failure of the bituminous surfacing."

A comparatively recent technique for the prevention of reflective cracking has been the use of heavy compactors by the States of Minnesota and Washington. As reported in 1961 by Paul G. Velz[8] the use of a 59 ton pneumatic roller over a concrete pavement prior to the application of an A.C. overlay resulted in definite and sizeable reductions in the percentage of reflection cracks as compared to unrolled sections after six months of observations. It was noted that rolling had very little effect upon the roughness of the pavement. Undoubtedly the "pavement breaker rolling" served to reduce the magnitude of vertical movement. Another variation of this technique has been applied by the State of Washington as reported by J. L. Stackhouse, Maintenance Engineer[9]. In this instance a 4 mile concrete roadway built in 1924 was broken down with a pneumatic compactor. The pavement breaking not only reduced vertical slab movement but revealed weak spots in the structural section which could be dug out or drained. A 5 inch flexible base cushion course with a 3 inch surfacing was then placed.

After 18 months of traffic no reflection cracking appeared nor was any visual subsidence noted.

Mr. Stackhouse attributed most of the credit for the elimination of reflection cracking to "insulation" of the A.C. surfacing from the expansion and contraction of concrete slabs by the crushed stone layer. In addition, the cushion course eliminated the necessity of leveling the old roadway by using varying thicknesses of A.C. surfacing.

CALIFORNIA'S EXPERIENCE WITH FLEXIBLE BASE CUSHION COURSE CONSTRUCTION

A perusal of the Pavement Section files revealed only one report on an investigation by the Materials and Research Department of a project involving flexible cushion course construction.

This project, road X-Sol-7,8-H,B,A, contract 1-10TC62 near Cordelia is of particular interest since it appears to be the basis of a great deal of the criticism of this construction technique.

The westbound lanes, consisting of 3" of A.C. surfacing over 6" of aggregate base over old PCC pavement were paved during the months of October, November and December, 1952 and were opened to traffic about the middle of January, 1953. During this period approximately 14 inches of rain fell in the Fairfield area. Severe raveling occurred immediately after the roadway was opened to traffic. When it became apparent that localized patching was inadequate, the westbound traveled lanes between stations 271 and 410 were scarified, aerated and relaid. There can be little doubt that the surfacing was initially quite permeable since the average field moisture content of the A.C. cores taken in March, 1952 was 6.6% and ranged from 3.2 to 9.6%.

The results of tests on the aggregate base samples indicated a high percentage passing the No. 200 sieve (9 to 16%) although all R-value tests were above the specification limit.

The failure was attributed, therefore, to severe pumping of mud fines into a saturated surfacing. The clay particles in the base virtually "emulsified" the surfacing as evidenced by the brown hue noted during the investigation and the ease with which the surfacing was bladed off the roadway during the blanketing operation. A further indication of the effect of this water action on the surfacing was the results of stability tests on recovered cores at room temperature which averaged 21 as opposed to 40 at 140°F. after drying the excess water from the cores.

An investigation by District VI of the distress on a cushion course project (Project VI-Mad-4-B) was reported by Mr. A. H. Green in a memo to J. G. Sprague dated August 31, 1956.

The structural section consisted of a 20 foot PCC slab with thickened edges placed in 1930. After ten years the slabs began to show faulting. In 1944, after mudjacking, the slab was blanketed with 1½ inches of A.C. However, cracking reflected through the surfacing and in 1951 this portion of the roadway was overlaid with 6 inches of aggregate base and 3 inches of A.C. surfacing. In addition, the roadway was widened 4' to the right. As a result 4 feet of the right 12' lane consisted of 3" A.C. over 6" A.B. over a 6" oil mix shoulder.

The aforementioned report noted that the majority of the distress occurred over the widened area (the outer wheel track). The report stated further: "The failures, or areas of pavement distress are evidenced by settlement of portions of the roadway surface into longitudinal ruts".

It was also noted that the surfacing material was coated with a fine silt or clay, and that seepage had occurred at the junction of the PCC and shoulder section.

Under conclusions, the report continues, "The present settlement of the pavement was caused by either of two conditions or a combination of both. One cause is a consolidation of the rock base either by further compaction or removal of some of the fine material. The other cause is a consolidation of the material under or just beyond the widened strip which would allow some of the material to be displaced or squashed out laterally".

The conclusions drawn as a result of this investigation are, in the writer's opinion, open to some question. The appearance of "longitudinal ruts" in the outer wheel track are more likely to be the result of displacement of the basement soil than consolidation. The utilization of a 15 inch structural section with an 9.0 T.I. (used in the reconstruction design) results in a basement soil R-value requirement of 46. Although R-value tests on 2 samples of the native soil (a clayey sand) resulted in R-values of 65 to 67 for 300 psi exudation pressure, it appears likely that field moisture may have been considerably higher than the design level. The seepage at the PCC-shoulder interface and the evidences of severe pumping in the form of fines penetration into the A.C. mix point to the presence of free moisture in the structural section.

VISUAL INSPECTION OF CUSHION COURSE PROJECTS IN DISTRICTS 05, 06 and 10

On October 26, 1961, in a memo to the Materials Engineers of Districts 05, 06 and 10, it was requested these districts submit a list of those projects built since 1948, utilizing flexible base cushion course construction. As shown by the general breakdown in the following table, of a total of 43 projects submitted, only 4 were listed by the districts as failures:

District	No. of Projects	Condition		
		Fair to Good	Cracked	Failed
05	3	3	0	0
06	8	3	3	2
10	32	30*	0	2

*Except for the 2 projects designated as failures by District 10, all cushion course projects were considered successful. The degree of cracking on the "successful" projects was not delineated.

From January 15 to 18, 1962, the three districts concerned were visited and 18 of the projects submitted were inspected.

The following is a brief description of each project with visual observations:

	Project	Contract	Structural Section	Completion Date	Visual Observations
1.	05-SBt-2-B,A	1-5TC16F	4" AC 6" AB PCC	1951	Appears in excellent condition. No maintenance or blanketing since its construction in 1951.
2.	05-Mon-117-A	55-5TC6	4" AC 6" AB PCC	1955	Generally good appearance. Localized areas of "alligator" cracking with evidence of pumping on the low side of the superelevation. No depressions or spalling.

	Project	Contract	Structural Section	Completion Date	Visual Observations
3.	05-Mon-117-Mon	56-5TC1	5" AC 4" AB AC	1956	Appears in excellent condition. Any cracking has been obscured by the 1960 1" AC contact blanket.
4.	06-Ker-57-B	51-6VC1	2" RMAC 7" AB PMG	1950	Both the cushion course and contact blanket sections are in excellent condition. May not be a good example since old AC was "retempered". Low T.I. & dry weather.
5.	06-Ker-4-E,F	1-6VC45-F	1" OG AC 2" AC 4" Min AB PCC	1951	Periodic block and transverse cracking in traveled lane, primarily the outer wheel track. Some wheel track depressions in OWT beyond edge of old PCC. Cushion course section generally better condition than blanketed section.
6.	06-Tul-4-A	55-6VC12-F	3/4" OG AC 3" AC 6" AB PCC	1956	Periodic "Alligator" cracking with evidence of pumping confined entirely to the TL(OWT). Probably 10% patched or cracked. The OWT is not over old PCC.
7.	06-Tul-4-A	55-6VC25	3/4" OG AC 3" AC 6" AB PCC	1956	The first segment (Sta. 553 to 614) almost entirely free of distress. Localized block cracking in outer wheel track between Sta. 411 & 467. Generally in better condition than project No. 6, yet there is only one years difference in age. Again, the traveled lane outer wheel track is not over old PCC.
8.	06-Mad-32-A	53-6TC2	3" AC 6" AB Bit Mac	1952	Excellent condition.

	Project	Contract	Structural Section	Completion Date	Visual Observations
9.	06-Mad-32-A	54-6TC5	3" AC 6" AB Bit Mac	1954	Probably recently resurfaced.
10.	10-Mer,Mpa-18-A,A,I	51-10TC7	2" AC 4" AB PCC	1951	Excellent condition.
11.	10-Mer-18-Mer,A	54-10TC26	3" AC 4" AB PCC Also contact blanket section	1954	Cushion course section in good condition. Periodic transverse reflection cracks in contact blanketed section. Some outer wheel track patching.
12.	10-Mer-18-A	10TC17	2" AC 4" AB PCC Also contact blanket section	1947	Fair condition. Some transverse cracking and localized outer wheel track patching in both the cushion course and contact blanket sections.
13.	10-Mer-122-Gus,A	0-10TC37	2½" AC 6" AB AC	1948	Excellent to within ±1 mile of the San Joaquin River, then frequent patches in both wheel tracks.
14.	10-Mer-122-B	54-10TC13	2½" AC 6" AC	1954	Excellent, probably resurfaced.
15.	10-SJ-41-A	1-10TC43	2" AC 4" AB AC	1949	Fair condition. Periodic patching and block cracking in outer wheel track.
16.	10-Sta-13-A,Rvbk,A,Okdl,B	51-10TC2	2" AC 4" Min AB AC	1951	Good condition. Some transverse cracking.
17.	10-Sta-13-B	0-10TC32	2" AC 4" Min AB AC	1948	Good condition. Some transverse cracking.
18.	10-Sta,Tuo-13-B,A	55-10TC21	2½" AC 4" AB PCC Also new construction	1955	Cushion course sections in excellent condition.

	Project	Contract	Structural Section	Completion Date	Visual Observations
19.	10-Sta-41-A,B	0-10TC29	2" AC 4" AB AC	1948	Much transverse cracking between Vernalis and Westley. Continuous long thin outer wheel track patch, perhaps due to longitudinal cracking. New blanket from Westley to Newman.

In general the results of visual observations do not reveal any clear cut indications that the cushion course construction is more prone to failure than other methods of construction.

Without exception, on those projects which employed more than one method of construction, the cushion course sections were in as good or better condition than the contact blanket or newly constructed sections. A large part of the distress which was observed in cushion course sections occurred in the outer wheel track beyond the edge of the old concrete slabs (which were usually 15' in width).

FIELD INVESTIGATION OF TYPICAL CUSHION COURSE PROJECTS

The final phase of this study consisted of physical investigation of five projects which were built utilizing cushion course construction. Two criteria were used in the selection of projects for field investigations. The most important of these was the necessity of having other types of construction in addition to the cushion course to provide a basis of comparison. Thus, each project had sections of either new construction or A.C. blanket, built under the same contract as the cushion course. The second criteria was the selection of projects which had been in service for eight to ten years. This length of time is sufficient to reveal any significant variation in the performance of the different construction types while still early enough in the life of the project so that major reconstruction or repair should not have occurred.

The following is a summary of the visual observations, deflection measurements, and test results from the field investigation of the five test projects selected:

05-SBt-2-B,A
(San Juan Batista)

This project was completed in June, 1951, under contract 1-5TC16F and involved the widening of the existing two lanes of U.S. Highway 101 near San Juan Batista. Deflection measurements and sampling were accomplished in May, 1959, as part of a statewide asphalt concrete pavement performance study.

The northbound lanes, which were constructed entirely under the 1951 contract, consisted of 4" of A.C. surfacing, 8" of crusher run base, and 12-15" of imported subbase. Portions of the southbound lanes consist of a 9"-7"-7"-9" by 20' PCC slab which was overlain with 6" of crusher run base and a 4" A.C. surfacing. Visual observations revealed that the southbound cushion course constructions were uncracked. In the northbound (new construction) lanes, both travel lane wheel tracks were cracked throughout the length of the project, while the passing lane remained uncracked. On Figure 1 is shown the results of deflection measurements, a condition survey, and the coring logs of a 1000' section of the roadway in which both cushion course and new construction were used. The average deflection measurement over the cushion course section (SBTL-OWT) was 0.009". This level of deflection is well below existing criteria for a 4" A.C. surfacing, which provides one explanation for the excellent performance of this section. Over the new construction, the average deflections were 0.021" (NBPL-IWT) and 0.027" (NBTL-OWT). These deflections exceed the existing tolerable limit (0.017") for a 4" A.C. surfacing. Prior to cracking, the travel lane deflections were probably closer to the values shown for the uncracked passing lane. Cracking has not progressed to the passing lane, however, due to its lesser T.I. The results of tests on recovered asphalt from the three cores taken from the test section are presented in Table 1. There is a very marked difference in the recovered penetrations and ductility of the cores from the new construction and the cushion course section. The northbound travel lane core, with a recovered penetration of 15 and ductility of 17, reveals a much greater degree of weathering and hardening than the cushion course core, with a recovered penetration of 58 and a ductility of 100+. Physical examination of core no. 1 from the travel lane of the new construction revealed the penetration of fines into the bottom portion of the level course and an asphalt binder with a generally dead appearance. This was in marked contrast to the black and shiny appearance of the core from the travel lane of the cushion course section.

10-Sta,Tuo-13-B,A (Oakdale)

This project was completed in December, 1954, under contract 55-10TC21 and sampled in April, 1963. The cushion course section consisted of a 2½" A.C. surfacing over a 4" aggregate base over an existing 15' wide PCC concrete slab.

The new construction (including the two 4.5' widening strips on both sides of the old PCC pavement) consisted of a 2½" A.C. surfacing over 6" of aggregate base over 6" of aggregate subbase. Inspection of the roadway revealed that virtually all visible distress is confined to the all new construction. This distress is in the form of scattered hairline cracks predominantly in the outer wheel track. To provide the basis of comparison, samples were taken at two locations, in the inner wheel track over the cushion section and in the directly adjacent outer wheel track consisting of all new construction. The core logs, deflection measurements, and results of the condition survey for each location are shown in Figure 2.

For both test sections average deflection measurements over the cushion course section were well below those over the new construction (0.006" and 0.010" as compared to 0.025" and 0.027").

As was the case with Project 05-SBt-2-B,A, utilization of the existing PCC slab resulted in a very low level of deflection. Deflections over the new construction, while not unusually high, are in excess of the tolerable limit for a 2½" A.C. surfacing (0.023") and, thus, may be considered a likely contributing factor to the limited distress which has occurred. Visual examination of cores from both types of construction reveal that the mix has a slightly dull to shiny appearance with no indication of pumping or infiltration of fines. Tests on recovered asphalt (Table 1), however, reveal that the recovered properties of the binder from the cushion course section are slightly but significantly better than those from the new construction. Since, as previously mentioned, no evidence of pumping was apparent in either type of construction, the higher quality of the binder from the cushion course sections may possibly be attributed to the lower level of deflection to which the mix has been subjected during its service life.

06-Ker-4-E,F
(McFarland)

This project was completed in July, 1951, under contract 1-6VC45-F, and sampled in May, 1963. The construction involved the widening of the existing 20' PCC slab to 24' with 4" of untreated rock base over 4" of salvaged shoulder material. A 6" aggregate base cushion course and a 3" A.C. surfacing were then placed over the entire roadway. Over another section, the original slab was widened as previously described and blanketed with 3" of A.C. surfacing. This project afforded an excellent opportunity to compare the performance of a blanket, new construction, and a cushion section on a roadway with a high T.I. (9.0). Visual inspection of the project revealed that most of the widening strip (travel lane OWT) was cracked in varying degrees throughout the length of the project. In some areas this distress had deteriorated to the point that spalling and pumping were clearly evident. Scattered "alligator" cracking was also visible in the inner wheel track of the northbound travel lane (cushion course construction) although, in general, the cushion sections were in visibly better condition than the new construction.

In the blanketed sections, reflected shrinkage cracks from the old PCC pavement were visible in both lanes. In portions of the travel lane inner wheel track, this distress had deteriorated into block cracks.

Samples were taken at four locations considered representative of the different types of construction. At three of these locations, pairs of samplings at the same station were made in two different types of construction. Coring logs, deflection data, and the results of the condition survey of the four test areas are shown in Figure 3. Average deflection values for each type of construction were as follows:

Cushion course	-	0.005"
Contact blanket	-	0.008"
New construction	-	0.017"

Although the level of deflection for the entire project was uniformly low for all types of construction, the measurements taken over the new construction were significantly higher than those resulting from the blanket or cushion construction. The level of deflection is not considered to be a factor in the distress which has occurred in this project, however.

The results of tests on recovered asphalt (Table 1) indicate that, in general, the asphaltic binder from all three types of construction has weathered to a state of critical hardness although, with one exception, the properties of recovered asphalt from the cushion course section are markedly better than those from the other types of construction.

10-SJ-97-A
(Lockeford)

This project was constructed in 1954 under contract 55-10TC4 and sampled in February, 1963. The existing 20' wide A.C. pavement was leveled with a variable thickness of aggregate base and surfaced with 3" of A.C. Visual inspection revealed periodic "alligator" or longitudinal cracking in the outer wheel tracks, with isolated areas of spalling and rutting. Virtually no distress was found in the inner wheel track. On Figure 4 is plotted the results of deflection measurements, a condition survey, and the coring logs for each test section.

Deflections averaged 0.011" in the inner and 0.027" in the outer wheel tracks. Four of the five test sections averaged in excess of 0.030" deflection in the outer wheel track, which is well in excess of the existing criteria for a 3" A.C. surfacing. Although the exact limits of cushion course construction were not available, it appears that outer wheel track deflection measurements were generally higher regardless of the type of construction utilized. The results of visual inspection of cores and tests on the recovered asphalt indicate a slightly better performance by the blanket sections than the cushion sections. At four of the six test locations, however, the binder had reached or passed a point of critical hardness with respect to recovered penetration. Ductility, however, remained high at all but one sampling location. The only evidence of pumping on the project was noted at Sample Location No. 2 where fines had infiltrated ¼" into the A.C. at the bottom and at crack interfaces.

10-Cal-24-A
(Angels Camp)

This project was completed in 1953 under contract 53-10TC12 and sampled in November, 1963. The original roadway consisted of a 16' A.C. surfacing over a variable thickness of aggregate base. Under contract 53-10TC12 the roadway was widened to 22', with the outer wheel track consisting of 3" of A.C. surfacing over 4" of aggregate base over 8" of aggregate subbase. The existing travel way was blanketed with a 4" aggregate base cushion course and 3" of A.C. surfacing except for certain portions which received only the 3" A.C. blanket. Visual inspection of the roadway revealed a few areas of "alligator" cracking in the newly constructed outer wheel tracks. One short portion of the outer wheel track was rutted. The entire roadway, however, was in generally good condition considering its 10 years of service life. Coring logs, deflection data, and the results of the condition survey of the four test areas are shown in Figure 5.

Average deflections in the inner wheel track were approximately equal over both the cushion and blanketed sections, ranging from 0.007" to 0.011". Over the newly constructed outer wheel track, average deflections ranged from 0.019" to 0.029", with individual measurements as high as 0.041". The outer wheel track measurements are, thus, well in excess of the existing limiting criteria for a 3" A.C. surfacing. It is not unlikely, therefore, that high transient deflections were a key factor in the distress which has begun to manifest itself in the outer wheel track of the subject roadway.

Examination of cores from all types of construction revealed that the mix was rich and shiny in appearance with no signs of pumping or infiltration of fines. Properties of the recovered asphaltic binder were good for a 10 year old A.C. surfacing. In every instance, ductilities exceeded 100. The recovered penetrations from the blanket cores were found to be the highest, average 35, while those from the cushion section averaged 30, and those from the all new construction, 25. It appears that the relatively high transient deflection over the newly constructed outer wheel track is accelerating the aging and hardening process of the A.C. surfacing.

General Evaluation of the Results of Field Investigations

The physical evaluation of projects selected for field investigation was accomplished by comparing four properties of the cushion sections with those of other types of construction built under the same contract. These properties were (1) visual appearance, (2) pavement deflection, (3) moisture content of base material, and (4) properties of recovered asphalt. Visual inspection of the projects revealed that distress was generally less for the cushion sections than the other types of construction. This was particularly true on project 06-Ker-4-E,F, where the contact blanket had failed to prevent reflection cracking from the old PCC pavement. Deflection measurements over roadways incorporating cushion course construction were, in all cases, lower than those taken over new construction and comparable to those taken over sections utilizing contact blankets.

The results of tests on cushion course base material are presented by Table 2. Of particular interest was the in-place moisture content of the cushion course material, because of the prevalent belief that cushion course construction tends to trap moisture between the old and new surfacing. These data indicate that at every sampling location in-place moisture contents, ranging from 2.2 to 4.8%, were well below the normal design moisture content (at 300 psi exudation pressure) of base material. It is believed that this finding is particularly significant considering the fact that four of the five projects were investigated during the winter or spring.

Visual examination of asphalt concrete cores did not reveal any general evidence of water entrapment or pumping, as evidenced by infiltration of mud fines, in the cushion course construction. This is also shown to be the case by Table 3 which presents the moisture contents from the different types of construction at identical stations on the roadway. It can be seen there is no significant variation in moisture content.

With the exception of one project, the properties of the asphalt recovered from the cushion sections were as good or better than those from the other types of construction. These findings correspond with the results of deflection measurements and visual observations.

TABLE 1

Project	Core No.	Core Location	Type of Construction	Pavement Condition	Core Condition	Recovered Asphalt Tests		
						Pen(77°F)	S.P.	Duct(77%)
V-SBt-2-B,A 1-5TC16-F 1951	1	Sta. 264± OWT* NBTL**	New	Badly Block Cracked	Level & surface course separated. Fines between courses which had penetrated into bottom of level course. Asphalt "dead" in appearance.	15	158	17
"	2	Sta. 264± IWT NBPL***	New	Good	A fair appearing core. Some evidence of un-coated fines.	31	145	62
"	3	Sta. 264± OWT SBTL	Cushion	Good	No cracks or any evidence of un-coated fines. Asphalt appeared alive.	58	128	100+
X-Sta,Tuo-13-B,A 55-10TC21	1	Sta.631+50 IWT EBL	Cushion	Good	Mix has slightly dull to shiny appearance.	31	135	100+
"	2	Sta.631+50 OWT EBL	Widening	Good	No indication of pumping or in-filtration of fines.	18	144	84
"	3	Sta. 652± IWT EBL	Cushion	Good	"	24	138.5	100+
"	4	Sta. 652± OWT-EBL	Widening	Good	"	23	139	100+

*Outer wheel track **Northbound travel lane ***Northbound passing lane

TABLE 1 (Contd)

Project	Core No.	Core Location	Type of Construction	Pavement Condition	Core Condition	Recovered Asphalt Tests Pen(77°F)	S.P.	Duct(77%)
X-SJ-97-A 55-10TC4	1	1.22' N Mi. 9.95 SB-OWT	Cushion	Cracked - Slight depression.	Mix is tight. No infiltration of fines. Black & shiny appearance.	13	143.5	0
"	2	800' S of Mi. Mkr. 8.0 SB-IWT	Cushion	Cracked	Some evidence of pumping, fines infiltration, ¼" up from bottom & at crack interfaces. Intimate part of mix is black but dead in appearance.	21	137	100+
"	3	Mi.Mkr.9.95 NB-OWT	Blanket	Good	Good appearance. Black & shiny. Dense.	28	131	100+
"	4	1.0 Mi. N. of Harney Lane NB-IWT	Blanket	Good	"	16	140.5	100+
"	5	Mi.Mkr.8.0 NB-OWT	Blanket	Good	"	25	133	100+
X-Cal-24-A 53-10TC12	1	Sta. 368± IWT WBL	Cushion	Good	Black, shiny with no signs of pumping or fines infiltration.	34	124.5	100+
"	2	Sta. 368± OWT WBL	New	Good	"	21	134.5	100+
"	3	Sta. 282± IWT WBL	Cushion	Good	"	25	131.5	100+
"	4	Sta. 282± OWT WBL	New	Good	"	28	131.5	100+

TABLE 1 (Contd)

Project	Core No.	Core Location	Type of Construction	Pavement Condition	Core Condition	Recovered Asphalt Tests Pen(77°F)	S.P.	Duct(77%)
VI-Ker-4-E,F 1-6VC45-F	1	"E"444+75 OWT NBTL	Widening	Allig. cr.	Some evidence of pumping & stripping. Fair condition.	18* 6**	137.5 163.5	100+ 0
"	2	"E"444+75 IWT NBTL	Blanket	Block cracked	Badly stripped. Very dry, brittle & dead in appearance.	8 3	162 169	0 0
"	3	"F" 42+00 OWT NBTL	Widening	Cracked	Rel. good app. Some ductile prop. No evidence of pumping.	16	144	47
"	4	"F" 42+00 IWT NBTL	Cushion	Good	Some evidence of pumping - no stripping. Fairly black and shiny.	20	141.5	100+
"	5	"F" 60+00 OWT NBPL	Widening	Good	Harder & more brittle than No. 4. Some ductile prop. No evidence of pumping.	17	136.5	100+
"	6	"F" 60+00 IWT NBPL	Cushion	Good	Black, alive looking. Some ductile prop. No evidence of pumping or stripping.	19	141	100+
"	7	"E"428+74 IWT NBTL	Blanket	Cracked	Complete infil. of mud fines. No evid. of stripping. Where no evid. of pumping asph. black & shiny.	22 10	145 152	30 0
"	8	"E"431+73 IWT NBTL	Blanket	Good	Dead in appearance. Very dense, tight. No evidence of pumping or stripping.	9 15	157.5 152	6 0

*Surface course **Level course

TABLE 1 (Contd)

Project	Core No	Core Location	Type of Construction	Pavement Condition	Core Condition	Recovered Asphalt Tests		
						Pen(77°F)	S.P.	Duct(77%)
X-Cal-24-A 53-10TC12 (contd)	5	Sta. 253± IWT WBL	Blanket	Good	Black, shiny with no signs of pumping or fines infiltration.	31	130	100+
"	6	Sta. 230± IWT WBL	Blanket	Good	"	32	133	100+
"	7	Sta. 184+50 IWT WBL	Blanket	Good	"	42	128	100+
"	8	Sta. 282± IWT EBL	Cushion	Good	"	31	131.5	100+
"	9	Sta. 282± OWT EBL	New	Good	"	27	131	100+

TABLE 2

Results of Tests on
Cushion Course Material

Project	Station	% Passing 1"	No.4	No.200	R-Value	S.E.	Field Moist.%	Design Moist.%
V-SBt-2-B,A Cont. 1-5TC16-F	264+00 SB-TL	99	60	10	81	53	3.5	7.6
X-SJ-97-A Cont. 55-10TC4	322' N Mi. 9.95	98	64	4	81	89	3.4	6.5
"	10' N. Mi. 8.0	100	53	3	80	90	4.1	7.2
X-Sta,Tuo-13-B,A Cont. 55-10TC21	631+50 EB-IWT	100	54	10	85	46	3.6	7.0
"	652+00 EB-IWT	100	47	8	84	56	3.1	7.4
VI-Ker-4-E,F 1-6VC45-F	42+00 NBTL-IWT	100	41	6	84	50	4.8	7.0
"	60+00 NBPL-IWT	100	49	7	85	43	4.4	7.6
X-Cal-24-A 55-10TC12	368+00 WB-IWT	100	50	6	79	50	4.1	7.6
"	282+00 WB-IWT	100	51	3	80	37	2.4	7.4
"	282+00 EB-IWT	100	56	10	82	32	2.2	7.4
							3.5	7.3

TABLE 3

Surfacing and Base Moisture Contents
for Cushion and New or Blanket Construction
at The Same Roadway Station

Project	Station	Moisture Content (%) Cushion Construction AC	Cushion Construction Base	Blanket or New Construction AC	Blanket or New Construction Base
V-SBt-2-B,A	264+50	---	3.5	---	4.0* 5.0**
X-Sta,Tuo-13-B,A	652+00	0.3	3.1	0.3	3.1
"	631+50	0.8	3.6	0.7	4.0
VI-Ker-4-E,F	41+50	1.1	4.8	1.1	3.6
"	58+85	0.6	5.8	0.8	4.4
X-Cal-24-A	282 (WB)	1.0	2.2	0.5	2.4
"	" (EB)	0.7	2.2	0.6	2.2
"	368	0.6	4.1	0.7	4.1

*TL-OWT **PL-IWT

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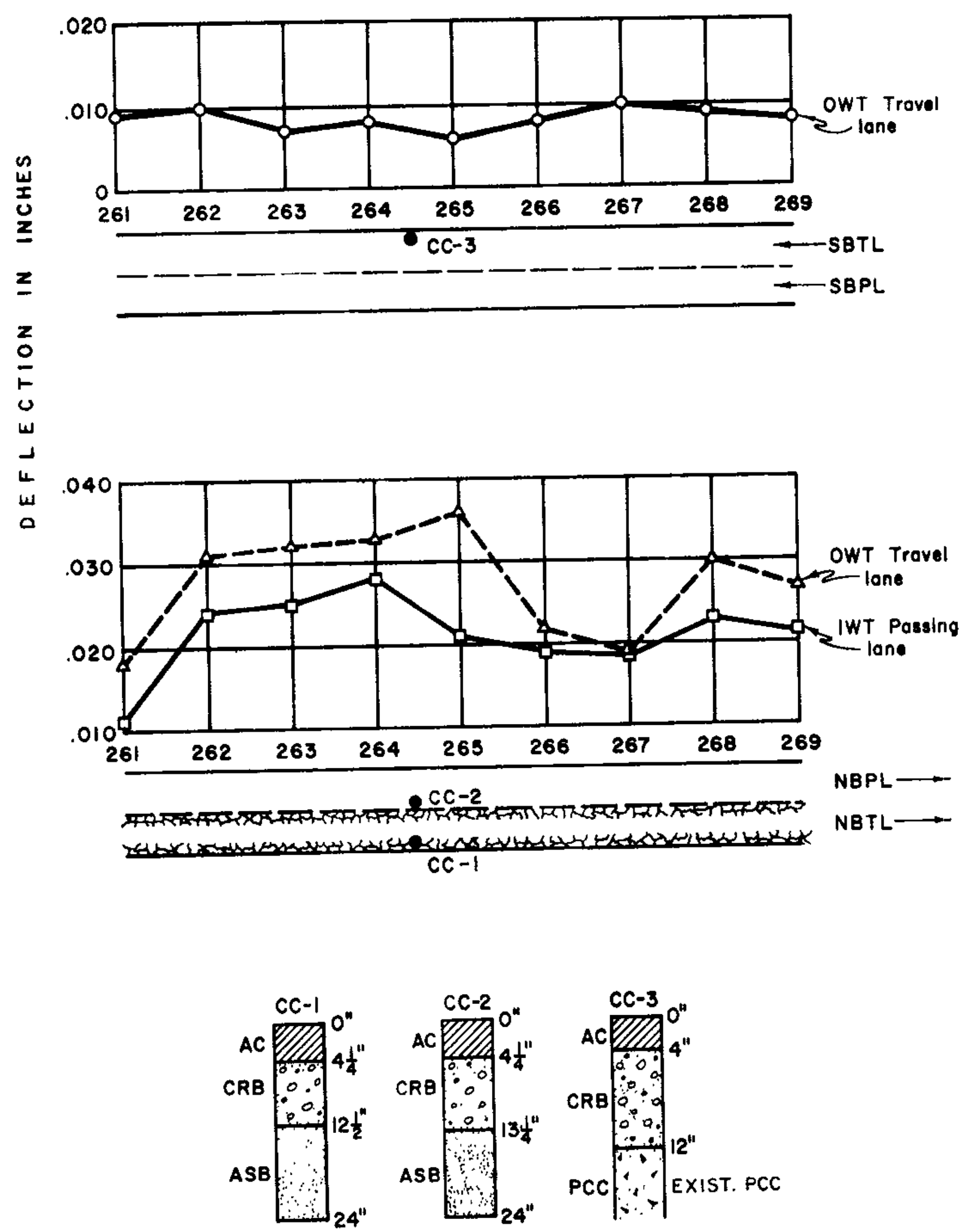
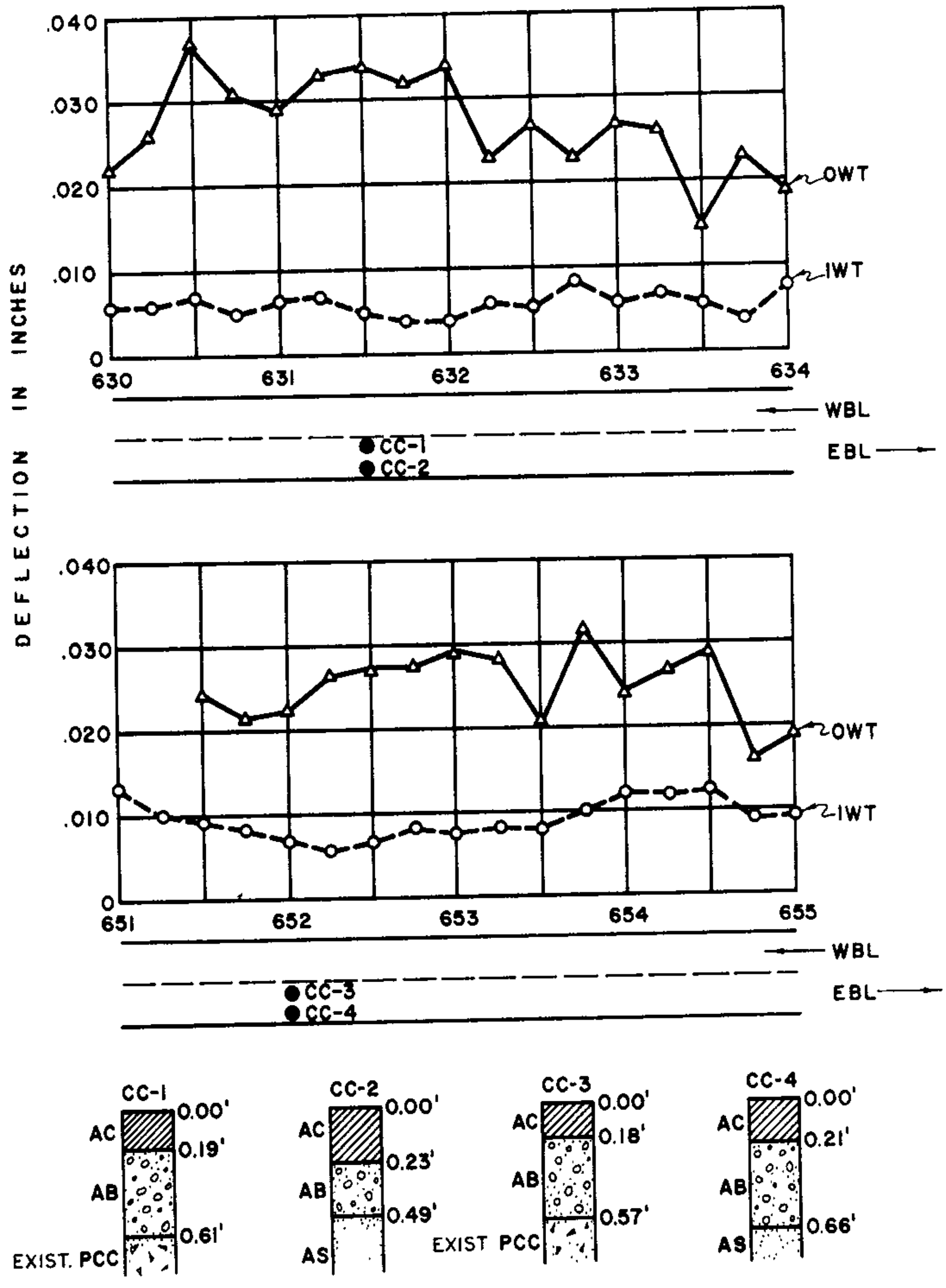


STATE OF CALIFORNIA DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT

PROJECT CORING LOCATIONS,
AREAS OF DISTRESS DEFLECTIONS
V SBt -2-B, A
Sta. "B" 261+00 to 269+00



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PROJECT CORING LOCATIONS,
AREAS OF DISTRESS DEFLECTIONS
X STA, TUO-13-B, A
Sta. 630 to 634 and Sta. 651 to 655